SIMULTANEOUS OCCURRENCES OF LUNAR HALOS AND CORONAS.

By C. F. BROOKS, Meteorologist.

[Dated: Weather Bureau, Washington, Mar. 5, 1919.]

The simultaneous occurrence of a lunar halo and corona is not such a rarely observed phenomenon as that of a solar halo and corona, for the brilliance of the sun is adverse to frequent observation of the solar corona. The following note appeared in Meteorological Office Circular.[1] (London) 21, February 26, 1918, page 3:

> Capt. C. J. P. Cave writes from Stonehenge: "A halo and a corona around the moon were visible here at 11 p. m. on February 21. Rippled clouds had come up from the northwest about 6:15 p. m. and the beginning of a halo had been seen when they reached the neighborhood of the moon; before 7:30 the rippled appearance had disappeared, but the sky was covered with a thin sheet of cirro stratus, through which the brighter stars could be seen; a very striking halo was visible from this time till 11 p. m. About this time a corona also became visible, two red rings being seen. Almost at the same time part of the halo was hidden by low clouds, and in a few minutes these drifted over, and both halo and corona disappeared. The phenomenon was very striking and must be very rare; two thin cloud sheets are necessary for its production; the upper one must be sufficiently thin to allow enough light to pass through to produce a corona, and the lower sheet must be thin enough not to hide the halo; moreover the moon must be of sufficient age to be bright enough for the phenomenon to be seen."

Capt. Cave's conclusion does not seem to apply in two recent observations of mine. At College Station, Tex., September 18, 1918, I made the following note: "At 10 p. m. [90th Meridian 'Summer' time] there was a colored, large, double corona (due to the water-drop A.Cu. clouds), a fine, unbroken halo (due to the snow falling from the A.Cu.), and an annulus (due to the raindrops formed from the melting snow)." On February 12, 1919, at Washington, D. C., I have this note: "At 10:20 [p. m. 75th Meridian Time] the high clouds [Ci.St. and Ci.Cu.] had thinned appreciably and the halo had become bright colored. There was a corona (single ring, radius about 3°) at the same time." In this case, also, the water-drop clouds seem to have been above or in the falling snow which produced the halo, for the texture of the Ci.Cu. elements of the general cloud sheet were indistinct. In both cases the moon was two days before full.

Thus, it seems that another explanation for the simultaneous occurrence of halo and corona is, that the halo forms in a sheet of snow which is falling out of, or through, clouds of (undoubtedly undercooled) water drops, or spheres of clear ice,[2] and that when an annulus is observed with a halo, there is every reason to believe that the falling snow crystals which make up the Ci.St. sheet are reaching a level where they are melting into fine raindrops.

LUNAR HALO AND PARASELENIC CIRCLE OBSERVED AT COLONY, WYO.

Through the official in charge at Cheyenne, Wyo., Mr. Cola W. Shepard, Cooperative Observer, reports that a lunar halo and a paraselenic circle were observed at Colony, Wyo., on January 10, 1919. Both circles were complete and very distinct. They were brightest at about 9 p. m., but had been visible for some time before this.—*W. R. G.*

[1] The British Meteorological Office Circular is primarily a means of communication between the office and observers. It is an octavo leaflet of 4 pp. issued monthly since June, 1916.

[2] Cf. G. C. Simpson, Coronae and Iridescent Clouds, Quart. Jour. Roy. Met. Soc., Oct., 1912, vol. 38; and recent discussions in Symons's Met. Mag., 1917, vol. 52, by Simpson, pp. 17-18, and E. C. Barton, pp. 31-32.

NOTES ON THE COMPARISON OF ANEMOMETERS UNDER OPEN-AIR CONDITIONS.*

By A. NORMAN SHAW

[Dated: McGill University, Montreal, Quebec, Feb. 8, 1919.]

CONTENTS.

Section 1. Introduction.—The comparison of anemometers has occupied considerable attention especially since the rapid development of aeronautics, and the accuracy of the ordinary instruments is fairly well known. There has, however, been occasional difficulty in correlating tests and calibrations made under the controlled conditions of the "wind tunnel" or the "whirling table," with the practical usage of the instruments in fluctuating open-air conditions. The electrical or "hot-wire" anemometer[1] and the kata-thermometer[2] as an anemometer do not appear yet to have received the extensive application for which they are apparently fitted, and very little attention seems to have been directed toward their adaptation for use under open-air conditions.

It is the object of these notes to discuss some observations of possible interest in this connection, which were taken at Father Point Experimental Station in September and October, 1917, during the acoustic surveys of Dr. L. V. King. Meteorological observations[3] were required in order that the influence of atmospheric structure on the propagation of sound might be studied, and through the kind permission of Sir Frederick Stupart, director of the Dominion meteorological bureau, Mr. J. Patterson of that department joined Dr. King's party and brought with him a supply of standard meteorological instruments and accessories. It was in association with Mr. Patterson at this time that the present writer became interested in these instruments.

The hot-wire anemometer tests were made at the suggestion of Dr. King, with his recently developed portable outfit which had been brought down to the experimental station.

The kata-thermometer was in use by the writer for some humidity investigations, and when this opportunity presented itself it was thought of interest to test the claims of the designers with reference to its application as an anemometer.

It should be pointed out that these notes are the result of observations incidental to another investigation and consequently they are somewhat incomplete, but as the comparisons were not continued it was thought that they were of sufficient interest to be recorded with this explanation.

* These notes were made in connection with work performed under the auspices of the Honorary Advisory Council for Scientific and Industrial Research in Canada, who very kindly gave permission for their publication.

[1] See L. V. King, "The linear hot-wire anemometer and its applications in technical physics," Jour. Frank. Inst., Jan., 1916, pp. 1-25, where a complete list of references is given. Also J. S. G. Thomas, "Hot-Wire Anemometry," Sci. Am. Sup., Feb. 15, 1919, (pp. 106-107): and T. S. Taylor, "A new type of hot-wire anemometer," abs. Phys. Rev. (2nd Ser.) xiii, Feb., 1919 (pp. 146-147).

[2] Hill, Griffith and Flack, "The measurement of the rate of heat-loss at body temperature by convection, radiation, and evaporation," Phil. Trans. Roy. Soc. London, B., vol. 207, p. 201 (1915).

[3] The meterological observations are discussed by Mr. J. Patterson and the present writer in sections of Dr. L. V. King's Report to the Honorary Advisory Council of Scientific and Industrial Research, on "The acoustic efficiency of fog-signaling, Father Point experiments, 1917."

Section 2. The Robinson cup anemometer compared with pilot balloons under open-air conditions.—A comparison between the values of wind velocities determined with a Robinson cup anemometer and those calculated from observations on a pilot balloon drifting past it is of interest as a check calibration under conditions of practical usage.

The pilot balloons, which were employed in these tests, consisted of thin rubber envelopes filled with pure hydrogen, and had a dead weight of about 3 grams and a free lift of about 8 grams. They rose, when released, with a velocity of approximately 80 meters per minute. Observations on their movements were made with a theodolite at the end of each successive minute after their release.

Table 1 gives a comparison between the average horizontal velocities calculated for the first minutes of their respective ascents and the velocities as determined from the Robinson cup anemometer on the top of the standard 40-foot meteorological tower at Father Point. The readings are recorded only for cases when the balloons moved during the first minute in an approximately straight line and when there was a negligible velocity gradient in that interval.

The calculation of the velocities and the directions were made from the theodolite readings by the formulae

$$V_1 = h_1 \cot c_1 \text{ and } \theta_1 = a_1 + b$$

where V_1 is the average velocity during the first minute; h_1 is the height at the end of the first minute; c_1 is the angle of elevation; θ_1 is the "true bearing"; a_1 is the azimuth reading; and b is the correction necessary to reduce the theodolite readings for a to true bearings.[4]

The Robinson cup readings were obtained from the standard instrument and records at the meteorological station. The recorder gave the value of the wind equal to three times the velocity of the cups. This was corrected by Marvin's formula,

$$\log V = .079 + .901 \log v,$$

where V is the velocity of the wind, and v is *three times* the velocity of the centers of the cups each expressed in miles per hour.[5]

TABLE 1.—*Comparison between Robinson cup and pilot balloon observations under open-air conditions.*

Date.	Robinson cup at elevation of 40 feet (corrected values).		Pilot balloon average up to elevation of approximately 260 feet.	
	Mi./hr.	*Dir.*	*Mi./hr.*	*Dir.*
Sept. 15, 4.30 p. m.	8	NE.	8	NE.
18, 4.00 p. m.	9	W.	10	W.
20, 3.20 p. m.	16	NE.	16	NE.
22, 1.50 p. m.	16	NE.	14	NE.
25, 10.17 a. m.	11	SW.	18	SW.
Oct. 3, 10.20 a. m.	21	SW.	21	SW.
5, 1.42 p. m.	10	W.	10	W.
10, 2.06 p. m.	16	NE.	16	NE.
10, 3.31 p. m.	14	NE.	14	NE.

[4] The general expressions for V_n and θ_n, respectively, the velocity and direction during the *n*th minute after release, are:

$$V_n = \{(h_{n-1} \cot c_{n-1})^2 + (h_n \cot c_n)^2 - 2 h_{n-1} h_n \cot c_{n-1} \cot c_n \cos (a_n - a_{n-1})\}^{1/2}, \text{ and}$$
$$\theta_n = \sin^{-1}\left\{\frac{h_n \cot c_n \sin (a_n - a_{n-1})}{V_n}\right\} + a_{n-1} + b.$$

If it is desired to consider the whole course of the balloon it is, however, easier to determine the values of V and θ by making a plan of the path of the balloon from the projections of its positions, and then obtaining the successive values graphically from it.

[5] For a description of this standard outfit which is similar to that adopted by the Weather Bureau in the United States, see "Instructions for the installation and maintenance of wind measuring and recording apparatus" Circular D, instrument division. Weather Bureau, U. S. Dept. of Agriculture.

The letters N, S, E, and W refer in the customary manner to the direction *from* which the wind blows. There was no general agreement closer than the nearest mile per hour as given. Each determination of the balloon values was made as in the following sample case:

Sept. 15, 4.30 p. m.—Theodolite readings:

$$a_1 = 135° \text{ and } b = 102°.$$
$$c_1 = 21.1° \qquad h_1 = 260 \text{ feet.}$$

hence $V_1 = h_1 \cot c_1 = 8$ mis./hr. approximately; and $\theta_1 = a_1 + b = 237°$; therefore 57° is the bearing of the direction from which the wind was blowing, which we may call NE., as the standard wind vane recorded the compass directions only to eight points; the value of b was determined by a theodolite comparison of the bearing of the Father Point Lighthouse with that of the pole star; the value of h_1 was determined from Hergessel's curves from the ascent velocity of small spherical balloons filled with hydrogen, expressed in terms of the dead weight and the free lift.[6]

There was at first some doubt about the interpretation of these curves and the formula which they represent, for balloons as small as those used, especially as the use of Dines's formula, gave a slightly different value for the ascent.[7] This was, however, checked by a comparison with the results obtained with a larger balloon having a free lift of about 100 g. and a dead weight of about 30 g. The assumption of 80 meters per minute for the smaller balloons gave approximately the same results for the wind velocities at given heights as were calculated by means of the larger balloons for which Hergessel's and Dines's formulae agreed.[8]

Section 3. The Robinson cup anemometer compared with a simple Pitot tube anemometer under open-air conditions.—A comparison of the Robinson cups and the Pitot tube under open-air conditions, was undertaken in connection with tests on a simple but sensitive form of Pitot tube which was required for the acoustic surveys. It was desired to test the suitability of the tube for the indication of gustiness, and as a preliminary it was compared with a Robinson cup anemometer which had been standardized.

Two Pitot tubes were employed, and each consisted of a U tube of about 8 mm. internal diameter, with its ends bent both in the same direction at right angles to, and in the same plane as, the U part. One end was open and the other was tipped with a *polished* brass cylinder having a closed conical end. Around the side of the cylinder were six small holes each slightly less than a millimeter in diameter. The U was half filled with gasoline and was mounted on a stand which could be tilted to any desired angle in order to increase the sensitiveness for low velocities.

It is now generally accepted that the formula

$$V^2 = 2P/\rho$$

deduced for this type of Pitot tube from Bernoulli's theorem for stream line motion in fluids—where V is the velocity of the wind, P the pressure (in absolute units of force) on the open side, and ρ the density of the air—may be applied in the interpretation of the observations.[9]

[6] Hergessel, Sixième Reunion de la Commission Internationale pour l'Aerostation Scientifique, 1909.

[7] The formula $V^6 = kL^3/W^2$ where V is the velocity, k a constant, L the free lift and W, the weight. Dines's, Meteor. Oft. London Pub. M. O. 202, p. 27.

[8] A discussion of American methods of reducing pilot-balloon observations will appear in an early issue of the REVIEW.—ED.

[9] Hunsaker, "The Pitot tube and the inclined manometer." Smithsonian Publication No. 2368, p. 27 (1916); Bramwell and Page, "On the determination of the pressure-velocity constant for a Pitot (velocity-head and static-pressure) tube," Tech. Rep. of the Adv. Com. for Aeronautics (Brit.), 1912–13, p. 35; Rowse, "Pitot tubes for gas measurements." Pro. Am. Soc. Mech. Eng., April, 1913, p. 640.

The alteration of this formula to suit our particular readings is a simple matter.

Let v = the velocity in miles per hour.[10]

r = the reading in cm. of the gasoline on one side of the tube, i. e., the distance from the scale zero. Thus the "head" $= 2r$.

d = the density of the gasoline in grams per cc.

g = the gravitational acceleration constant in cm. per sec. per sec.

A = the angle of slope of the stand in degrees.

ρ = the density of the air in grams per cc.

Substituting in the above formula and multiplying by the required constants in order to express v in mi./hr., we get—

$$v^2 = 0.00200 \frac{r\ d\ g\ \sin A}{\rho}$$

In our case $d = 0.75$ gm./cc., $g = 980$ cm./sec.^{2}, $\sin A = 1.32$, and $\rho = 0.00129$ gm./cc.[11], hence the formula reduced to

$$v^2 = 151\ r$$

In the same way formulae could be deduced for any particular slopes and densities. The two Pitot tubes were used in the comparisons, and the average readings for them during successive half-minute periods are given in the second column of Table 2. The method of averaging is discussed in the paragraphs following the table. The velocities given in the next column are calculated from these by the formula given. The two tubes were compared previously, in a fluctuating wind, and the tops of the corresponding liquid columns in each tube were found to keep very closely in line. Occasionally the free period of vibration of the gasoline affected the readings momentarily by as much as 1 cm., but this was infrequent and was apparently quickly damped. It was thought that damping devices could readily be introduced which would eliminate this entirely.

In the fourth column of the table the velocities as determined from the Robinson cups are given. The cups were mounted near the tubes, and the recording attachment was arranged to tick off on a chronograph every quarter of a mile of wind. The average value of the wind during each half minute was measured off afterwards from the chronogram and corrected by Marvin's formula.

In the last column of the table the constant of the Pitot tubes is given as calculated in each case independently in terms of the Robinson cup values, with the satisfactory average result shown. It is somewhat of an inversion to express an absolute method of measurement in terms of an empirical one, but it was of interest here to determine the constant of our Pitots in terms of a standardized instrument.

[10] "Miles per hour" was considered more convenient than "meters per sec." because the accuracy of the results was of the order of 1 mi./hr., and these units were also more convenient in other parts of the investigation.

[11] The average density ρ was calculated from the formula for moist air

$$\rho = 0.00464\ (B - 0.378\ p) / T$$

where B = the barometric reading in mm., p = the atmospheric aqueous vapor pressure in mm., and T = the absolute temperature. On the occasion of the observations recorded here, $B = 770$ mm., $T = 275°$ A, and $p = 4.05$ mm. B was obtained from the near-by meteorological station, and T and p were determined with standard instruments at the place of observation, the average being taken of readings obtained before, during, and after the tests.

TABLE 2.—*Comparison between Robinson cup and Pitot tube observations under open-air conditions.*

Observations.	Average reading of Pitot tube during half a minute. (r)	Average velocity of wind. ($v^2=151r$)	Average velocity of wind during the half minute, determined by Robinson cup. (V)	Constant for Pitot tube as determined from standardized Robinson cup readings. $\left(\frac{V^2}{r}\right)$
	Cm.	*Mi./hr.*	*Mi./hr.*	
	(Pitot No. 1)			
1	2.8	21	21	157
2	3.1	22	22	156
3	2.7	20	19	134
	(Pitot No. 2)			
4	2.6	20	20	154
5	2.6	20	20	154
6	2.6	20	21	170
7	2.6	20	21	170
8	2.5	19	19	145
9	2.6	20	19	139
	(Pitot No. 1)			
10	2.1	18	19	171
11	2.2	18	18	147
12	2.4	19	18	135
13	2.0	17	17	145
14[1]	0–0.2	0–5.5	3	....
Mean	....	....	....	152±2.4[2]

[1] This observation was taken at a different time.
[2] It was thought that the "probable error," ±2.4, could be mentioned reasonably, even with only 13 observations, because there are just as many Robinson cup readings above as below the mean, and the probable error of any one reading is less than 6 per cent (±8.6). (*Bessel's formula was used.*)

Section 4. Notes on the use of a simple Pitot tube for the analysis of gustiness.—It was somewhat difficult to get the average Pitot reading during half a minute, as the movements of the gasolene were sometimes momentarily erratic and rapid. As the gusts were approximately periodic the following method was adopted: The maximum and minimum readings during the half minute were recorded and their mean taken, also the mean position of the liquid was estimated by another observer and the mean of the two results was taken as representing approximately the average reading. The figures in Table 3 show the variations obtained in the case of the observations for the Pitots in Table 2; they give an indication of the sensitiveness of the instrument to fluctuations and show that it could readily be adapted to the study of gustiness.

TABLE 3.—*Fluctuations of the Pitot tube readings during the half-minute intervals.*

Observations.	Maximum reading.	Minimum reading.	Average of maximum and minimum.	Estimated mean reading.	Final mean. (r)	Average velocity. ($v^2=151r$)
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Mi./hr.*
1	5.0	1.2	3.1	2.5	2.8	20.6
2	5.0	1.5	3.2	3.0	3.1	21.6
3	4.0	1.4	2.7	2.7	2.7	20.2
4	4.2	0.8	2.5	2.7	2.6	19.8
5	4.5	1.0	2.8	2.4	2.6	19.8
6	3.5	1.1	2.3	2.8	2.55	19.6
7	4.0	0.9	2.4	2.8	2.6	19.8
8	3.5	0.9	2.2	2.8	2.5	19.4
9	4.0	1.2	2.6	2.6	2.6	19.8
10	3.0	1.0	2.0	2.2	2.1	17.8
11	3.0	0.6	1.8	2.5	2.15	18.0
12	4.0	1.0	2.5	2.3	2.4	19.0
13	3.2	1.0	2.1	2.0	2.05	17.6

It will be seen that in several cases the estimated mean readings are higher than the average of the maximum and minimum, but it must be understood that the accuracy of estimation and the magnitude of the fluctuations due to occasional free vibration, were sufficient to cause discrepancies of this kind, and the two determinations of the mean were made only for the purpose of obtaining a more reliable final mean.

Comparing the mean gust velocity calculated from the maximum readings (viz, 24.2 mis./hr.) and the mean lull velocity calculated from the minimum readings (viz, 12.5 mi./hr.) with the mean of the Robinson cup readings (viz, 19.6 mi./hr.) we get for the period of our test that the mean gust velocity is equal to 1.23 v, and that the mean lull velocity is equal to 0.65 v where v is the mean velocity determined from the standardized cups. The extreme gust velocity was 1.4 v and the extreme lull velocity (with the exception of observation No. 11) was 0.60 v.[12] These two latter values are too large because no correction has been made with reference to the dynamics of the vibrating column. The extreme readings would be affected appreciably on this account, but the correction could be ascertained.

Considering the fact that no recording or damping device was introduced, the general consistency of the figures in the table is perhaps more remarkable than is at first apparent. It should be noted that the probable error for a single mean by either method amounts to much less than 1 mile per hour in the calculated velocity. The extreme difference obtained in the unexplained variation of observation No. 11, amounts to 3 mi./hr., and there were only two other cases where the difference amounted to 2 mi./hr. In Table 2 it will be seen that the mean values for the wind during the whole test were in complete agreement for both types of instrument.

These tubes were used very successfully for recording the number of the gusts in a given period, as well as their comparative range and approximate velocity. A summary of some results obtained in this way is given by Mr. J. Patterson, and the present writer in a section of Dr. L. V. King's Report.[13] Checks were made on this method of indicating the frequency of gusts or double fluctuations of pressure (1) by watching the behavior of a small tethered pilot balloon, (2) by comparing with the record of a Dines's microbarograph, and (3) by counting the successive dark regions which were caused on the surface of the water on a day when the gustiness was very marked. A fair agreement was obtained.

Section 5. The hot-wire anemometer under open-air conditions.—In his work on the linear hot-wire anemometer, Dr. L. V. King describes a satisfactory portable form[14] with which precision measurements of both regular and turbulent flow can be performed to a much higher order of accuracy than can be obtained with any of the ordinary instruments. This outfit was brought down to Father Point and it had been hoped to test it thoroughly under open-air conditions with reference to its possible use in the study of gustiness and other problems of atmospheric structure. Unfortunately, owing to the press of the main investigation, there was not time even to complete a series of comparisons with the other anemometers. A preliminary test was, however, carried out: and it was sufficiently suggestive to justify these references here, and lead to the opinion that a method so promising should at once be recommended strongly for further development and application.

The fragility of the wires, the danger of their "burning out," and the extreme sensitiveness, were the only apparent disadvantages of the instrument for open-air work, and these were apparent because the apparatus had been taken outside just as it was, although designed for special laboratory tests. It is evident that disadvantages of this type should not present insuperable difficulties. The advantages that were immediately noted were striking. For sensitiveness and resolving power in indicating fluctuations, and for general range (provided that allowance was made for the influence of the atmospheric temperature on the constants of the instrument) it far surpassed the other instruments, while in regard to accuracy and freedom from error there does not seem to be any reason why precision results may not be obtained of the same order as those found generally in electrical measurements. In the field of aeronautical engineering the method should prove to be a most valuable aid.

The calibration curve for these instruments is of the form

$$V = A^2 (i^2 - B)^2$$

where V is the velocity of the flow, i is the electric current, and A and B are constants which can be determined[15] with accuracy, either directly from theory or by experimental calibration. In the case of the particular wire used at Father Point (No. 23 of Dr. King's calibrated set) the formula was

$$V = 3.24\ (i^2 - 0.715)^2$$

where V is the velocity in mi./hr. and i is the electric current measured in amperes.

The figures in Table 4 illustrate the type of observation obtainable. These readings were taken in 14 minutes as shown and were recorded each time the ammeter needle assumed temporarily a new mean position.

TABLE 4.—*Observations in the open air with the hot-wire anemometer.*

Time.	Ammeter reading. (i)	Calculated wind velocity. $V=3.24(i^2-0.715)^2$	Robinson cup averages. (V)
	Amperes.	*Mi./hr.*	
3.31 p.m.	1.51	7.9	The average velocity for half-minute periods varied from 3 mi./hr. up to 7 mi./hr.
	1.47	6.8	
	1.46	6.5	
	1.45	6.2	
3.37 p.m.	1.41	5.3	
	1.34	3.7	
3.38 p.m.	1.34	3.7	
	1.35	4.0	
3.42 p.m.	1.33	3.6	
	1.30	3.1	
3.44 p.m.	1.46	6.5	
Mean		5.2	5 mi./hr.

There was no object in making a closer comparison with the Robinson cup, since the hot-wire readings were mean values for short intervals of time while the Robinson cup readings were obtained only as averages for half-minute periods. A comparison of *self-recording* instruments of this type with others must be performed before a complete estimation of the value of the open-air use of this anemometer can be made.

Some simple tests of sensitiveness were made by blowing and fanning at various distances from the hot wire, and the claims of its designer in this respect appear to be justifiable. A further test made in comparison with the kata-thermometer is mentioned in the next section.

[12] Compare these four values with the results (1. 2 v, 0.75 v, 1.3 v, and 0.65 v, respectively) given by W. N. Shaw, in Report of the Adv. Com. for Aeronautics (Brit.), 1909-10, p. 97; also G. C. Simpson in M. O. Pub. 180, p. 37.

[13] Loc. cit.

[14] L. V. King, loc. cit., see p. 9 for photograph of outfit. Also see L. V. King, "On the convection of heat from small cylinders in a stream of fluid: Determination of the convection constants of small platinum wires with application to hot-wire anemometry," Phil. Trans. Roy. Soc. Lon. A vol. 214, p. 404 (1914), where a full treatment is given, and plates shown in illustration of the apparatus.

[15] As shown by L. V. King, loc. cit.

Section 6. The kata thermometer used as an anemometer.—The theory of the dry-bulb kata thermometer considered as an anemometer, is similar to that of the hot wire; in each case the velocity is obtained from observations depending on the rate of cooling of a hot cylinder. In the kata thermometer, however, the difference in temperature between 36.5° C., the average temperature of the bulb, and the surrounding air is such that the constant of the instrument varies appreciably with it and readings can be considered accurate only for low velocities; while in the case of the hot wire the difference is so large that for many ordinary purposes the constant may be taken as independent of the surrounding temperature, although the correction can be readily calculated when wanted.

The formula, $V=A(i^2-B)$,[2] given above for the hot wire becomes, since H varies as i^2,

$$V=a(H-b)^2$$

where V is the velocity as before, H is the heat lost in millicalories per square centimeter per sec., and a and b are the constants for the instrument and the particular units chosen. The constants are really functions of θ, where $\theta=(36.5-t)$°C. and t°C. is the surrounding temperature. It can be shown that $a=c/\theta^2$ and $b=d\theta$, where c and d are the remaining constants, and therefore, that,

$$V=c\left(\frac{H}{\theta}-d\right)^2$$

A full treatment of the theory of the instrument and its use is given by its designers,[16] and for the type used at Father Point, they give the equation $H/\theta=0.27+0.36\,V^{1/2}$ where V is in met./sec., which in the above form with V in mi./hr., becomes

$$V=17.2\left(\frac{H}{\theta}-0.27\right)^2$$

In Table 5 a number of observations are shown which illustrate the readings obtainable under open air conditions. The value H was obtained in the usual way by observing the time of cooling in seconds from 100° F. to 95° F. with a stop watch, and dividing this into the kata factor, which was 522 for our apparatus. The bulb was heated conveniently before observation by means of hot water carried in a thermos bottle. It was important to screen the bulb from direct radiations.

TABLE 5.—*Observations with the dry-bulb kata thermometer used as an anemometer under open-air conditions.*

Time of cooling. (ϕ.)	Rate of heat loss. ($H=522/\phi$.)	Temperature difference. $\theta=(36.5-t)$° C.	Calculated velocity. $V=17.2(H/\theta-0.27)^2$.	Robinson cup values (average for whole minute intervals). (V.)	Place of observation.
Seconds.	*mc./sec.*	°	*mi./hr.*	*mi./hr.*	
19.6	26.6	31.8	5.5	6	Near Robinson cup No. 2 at elevation of 6 feet.
18.8	27.8	31.8	6.3	6	Do.
23.8	21.9	31.8	3.1	3	Do.
20.8	25.1	25.9	8.4	10	Top of 40-foot met. tower.
19.2	27.2	25.9	10.5	10	Do.
14.0	37.4	29.7	16.9	([17])	Top of 80-foot lighthouse.
17.8	29.3	22.1	19.0	20	Near ground.

[16] Hill, Griffith, and Flack, loc. cit.
[17] 13 mi./hr. on 40-foot tower, ½ mile away.

As these Robinson cup readings are averaged over 1 minute intervals, while the kata readings are averages over the number of seconds shown, no closer agreement could be expected. The results are sufficient to demonstrate the apparent value of the instrument for obtaining the average wind velocity during the time of observation. A constant-temperature, electrically-heated bulb of this kind, arranged to self-record would probably be a valuable asset in many practical problems of anemometry.

The kata was also compared directly with the hot wire. In Table 6, the first column gives the value of V calculated as in Table 5, from the kata thermometer, and the second column gives the various values of V during the period of the kata observation which were obtained with the hot-wire instrument as in Table 4. The third column gives the mean value of the groups in the second column.

TABLE 6.—*Comparison of kata thermometer and hot-wire anemometer under open-air conditions.*

	The velocity as determined by the kata thermometer.	The velocity as determined by the hot-wire anemometer.	Mean velocity for hot-wire anemometer.
	Mi./hr.	*Mi./hr.*	*Mi./hr.*
1	6.3	6.7 6.5 6.2	6.5
2	3.3	3.7	3.7
3	3.1	3.6 3.1 3.2	3.3
4	[1] 11.1	11.5 11.2 11.9	[1] 11.5

[1] The readings in this case were not simultaneous.

The wet-bulb kata thermometer was also tried as an anemometer, but in the few tests made, was found to be much less satisfactory in open-air conditions. This is no doubt due to the extra evaporation factor, and there were indications that a correction might be needed in the formula which was used.[18]

It is desirable that the matter should be examined further before the observations can be satisfactorily interpreted. It is of some importance because if the formula had to be modified it would affect, also, the ordinary interpretation of the "comfort factor" in cases of strong wind or extreme drafts.*

Sec. 7. Additional remarks and summary.—A small turbine vane which had previously been calibrated in terms of a standard instrument was also tested in connection with one of the experiments. It gave under open-air conditions, the same results to within 1 mi./hr. as the Robinson cups and the Pitot tube, for averages taken over a minute. Tests were made on velocities up to 10 mis./hr.

In testing any of these instruments it was noticed that in gusty weather, it was essential either that the instruments compared, should be situated very near to each

[18] The formula given by Hill, Griffith, and Flack (loc. cit. p. 212) for the wet kata thermometer was $H=(0.27+0.36\,V^{1/2})\theta+(0.085+0.56\,V^{1/2})(F-f)^{4/3}$ where V is in met/sec. H and θ have the same significance as before, F is the max. vapor pressure in mm. at 36.5° C. and f is the existing vapor pressure in mm.

*Interesting discussions of the measurement of bodily comfort appeared in *Nature*, London, 1915, vol. 95: L. Hill, "Healthy atmospheres," pp. 205-207, contains pictures of the kata thermometer and caleometer; J. R. Milne, "*Man's true thermal environment*," p. 259, discusses Hill's article and describes a "psuchrainometer," an instrument to measure cooling; G. W. Grabiam's discussion of the inapplicability of the psuchrainometer to conditions in the tropics, and Milne's reply are on pp. 451 and 508. In the *Scientific American*, *May 8, 1915, p. 431*, there is a historical discussion, "Measuring atmospheric comfort." An account of experiments with "The kata thermometer as a measure of the effect of atmospheric conditions upon bodily comfort," was published by C. E. A. Winslow in *Science*, New York, 1916, N. S., vol. 43, pp. 716-719; and a somewhat similar one by A. N. Shaw in Trans. Roy. Soc. Canada, 1917, vol. 11, pp. 121-127.—C. F. B.

other, or that the average should be taken over a time which was at least five times longer than the period between gusts.

It was found throughout that comparisons of this kind were more trustworthy on occasions when the gusts seemed to be traveling as cylindrical eddies with horizontal axes. If the axes were tilted or vertical, the extra fluctuations in direction rendered the readings much more erratic and difficult to interpret. Near prominent topographical features, or buildings, such effects were very marked.

SUMMARY.

1. A comparison between the wind velocities determined with a Robinson cup anemometer at an elevation of 40 feet and those calculated from observations on a pilot balloon drifting past it, showed a very satisfactory agreement between the two methods of observation under open-air conditions.

2. A simple Pitot tube, which could be constructed with ease in any laboratory, was tested under open-air conditions and found to give satisfactory results with the theoretical formula $v^2 = 2P/\rho$.

3. Its use for the detection and measurement of gustiness was demonstrated. It was found that the relation between the mean gust velocity, the mean lull velocity, and the mean velocity could be satisfactorily investigated with a Pitot tube of this type.

4. The linear hot-wire anemometer as developed by Dr. L. V. King was tested under open-air conditions and appeared to be the most promising of anemometers from the standpoint of precision. The claims of its designer seem to be justified.

5. The kata thermometer which was used as an anemometer for various velocities up to 20 mis./hr. was found to give results in accordance with the other instruments.

Very many thanks are due to Dr. L. V. King for making these incidental tests possible while using the instruments for the acoustical investigation. To Mr. J. Patterson the writer is especially thankful for the opportunity to acquire experience and interest in meteorological work, and takes great pleasure in recording his indebtedness. It is also a pleasant duty to thank Lieut. E. Bieler for his kind assistance in taking simultaneous observations.

SOUTHERN CALIFORNIA WINDSTORM OF NOV. 24–26, 1918.

By FORD A. CARPENTER, Meteorologist.

[Dated: Weather Bureau, Los Angeles, Feb. 6, 1919.]

During November, 1918, southern California experienced the heaviest wind for more than two score years. The highest wind ever recorded since the establishment of the weather service in southern California occurred at Mount Wilson during this wind storm, when the anemometer registered 90 miles an hour.

The article by Special Meteorological Observer W. P. Hoge describes the beginning of this three-day wind and its effects, and his accompanying photograph of the

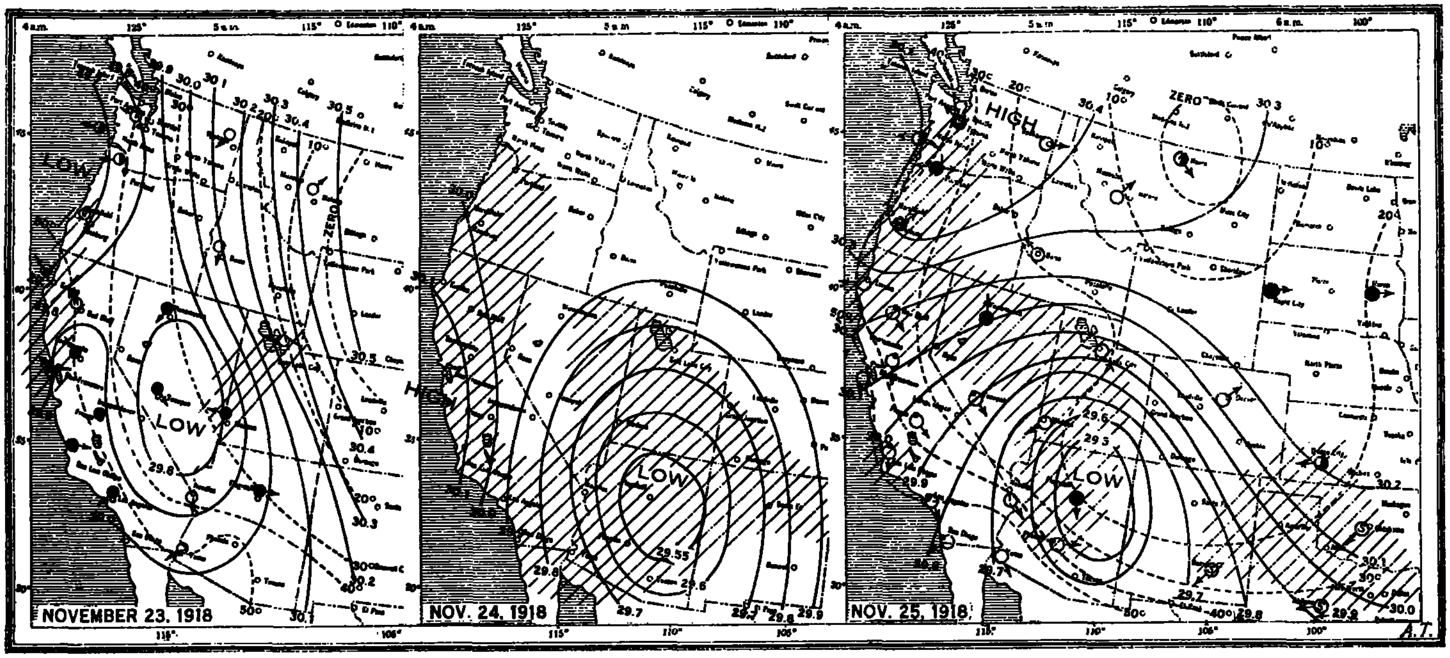

FIG. 1.—Weather maps showing successive positions of the southwestern cyclone, 5 a. m. (120th Mer. time), November 23, 24, and 25, 1918.

anemometer sheets shows the steadiness of the wind. The damage inflicted on the forest of Mount Wilson is well shown by his photograph (fig. 3) and may be duplicated in many portions of the forest reserve. Shortly after this storm my work took me into the mountains and I found many of the trails partially blocked by fallen timber.

The weather map of the morning of November 23 (fig. 1) showed a well-developed low area entering the southwestern Pacific coast. Storm flags were ordered by the district forecaster stating that a moderate to strong westerly gale would occur within the next 12 to 24 hours. The LOW progressed slowly eastward giving northwesterly gales throughout southern California. Like many disturbances of this character, the LOW disintegrated after three days of life; the weather map of the 25th showing the last distinctive formation of the LOW.

In order to show that the wind of November 23 was of unusual strength it is only needful to compare the curve of hourly velocity of that day with the mean hourly curve of the whole month. (See fig. 2.) The mean hourly ve-